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Deep learning inverse problems for exploration of matter in extreme conditions

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We recently devised a methodology within automatic differentiation (AD) which integrates our physics-priors into the specific IPs and deep learning representation together to perform Bayesian inference on the IPs. We demonstrated the developed methodology in several IPs raised in high energy nuclear physics (can also be easily generalized to other physics areas as well). (1) We first deploy the above AD-based approach to reconstruct spectral functions from Euclidean correlation functions which has been proven ill-posed especially with limited and noisy measurements. In our method the spectral is represented by DNNs while the reconstruction turns out to be optimization within AD under natural regularization to fit the measured correlators. We demonstrated and proved that the network with weight regularization can provide non-local regulator for this IP. Compared to conventional maximum-entropy-method (MEM), our method achieved better performance in realistic large-noise situation. It's for the first time to introduce non-local regulator using DNNs for the problem and is an inherent advantage for the method, which can promisingly lead to substantial improvements in related problems and IPs. (2) We applied the method to reconstruct the fundamental QCD force –heavy-quark potential –from lQCD calculated bottomonium in-medium spectrum. Both the radius and temperature dependence of the interaction are well reconstructed via inverse the Schroedinger equation given limited and discretized bottomonium low-lying states mass and width. (3) We also demonstrated the method's ability to infer neutron star EoS from astrophysical observables, with exciting results on closure tests for reasonable EoS reconstruction based on finite noisy M-R observables. Compared to conventional approaches our method holds unbiased representation for the EoS and bare interpretable Bayesian picture for the reconstruction.

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